THE ELECTROCARDIOGRAPHIC CHANGES AFTER GASTRECTOMY, ESPECIALLY ITS RELATION TO THE POTASSIUM DEPLETION

by

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The characteristic electrocardiographic changes were often observed especially after gastrectomy in the study of the postoperative serial electrocardiograms in abdominal surgery. Moreover, these changes seemed to have close correlation with postoperative clinical course. However, there are few papers which were concerned with the electrocardiographic change after gastrectomy. BUHR, studying 21 patients, described that a lowering amplitude of the T wave, a depression of the ST segment and a prolongation of the QT interval were observed after gastrectomy. RUF, RÖSCH & WALZ reported the same electrocardiographic changes in 15 patients. These authors stressed that the strain of sympathetic nerve or the anesthetic agent might be the primary cause of the electrocardiographic changes, however, they showed no interest in the relation between the electrocardiogram and the clinical symptoms.

The purpose of the present report is to analyse the postoperative electrocardiographic changes especially in the relation to the potassium depletion after gastrectomy.

METHOD AND MATERIALS

The serial electrocardiographic recordings, standard and precordial leads (CR_2 or V_2=R Ventricle, CR_4 or V_4=L Ventricle) were taken postoperatively untill the electrocardiogram returned to a normal pattern. The patients selected in this study showed normal electrocardiogram before operation, and digitalisation was avoided postoperatively because it disturbs the natural electrocardiographic change.

For the determination of the QT interval relative to the cycle length, the QT ratio was calculated from the GOLDBERGER's nomogram. The average normal QT ratio for men is 1.02. The maximum normal QT ratio for men is 1.08 and for women, 1.09.

The serum potassium concentration was determined on a flame photometer. The normal range was considered to be 3.1～5.5 mEq./L. in this study.

In animal experiment, using KÜHNS's method, the intracellular/extracellular relationship in heart muscle were determined.

RESULT

Postoperative complications, such as peritonitis, mechanical intestinal obstruction or circulatory collaps were able to bring marked changes in the electrocardiogram. Therefore, these factors must be excluded to evaluate the postoperative electrocardiographic changes. For this purpose, the serial electrocardiograms were recorded untill the changes returned to a normal pattern in these disorders. The patients

were selected who had no complication except illness.

1. The electrocardiogram in acute peritonitis.

The following two case reports are offered to illustrate the electrocardiographic change in acute peritonitis.

Case 1 (Fig. 1). F. Y., a 13-year-old female. Diagnosis : Acute generalized peritonitis due to perforation of appendix. She had full signs of acute generalized peritonitis when admitted to the hospital, and the electrocardiogram showed sinus tachycardia with marked depression of the ST segment. The T waves were still high in chest leads. Appendectomy and drainage were performed and during operation 200cc of blood and 1000cc of physiologic saline solution were given. The electrocardiogram taken 12 hours after operation showed marked improvement.

Case 2 (Fig. 2). S. K., a 39-year-old male. Diagnosis : Acute generalized peritonitis due to perforation of appendix. The electrocardiogram taken before operation showed sinus tachycardia and depression of the ST segment. The T wave in lead

Table 1. Electrocardiographic values in acute generalized peritonitis
upward deflection +mm
downward deflection −mm
mean value of QT ratio : 1.02

Patient No.	ST(deviation from base line)					T (amplitude)					RR	QT	QT ratio	U
	I	II	III	CR_2	CR_4	I	II	III	CR_2	CR_4				
1	0	−0.5	−0.5			3	1.5	−2			0.43	0.26	0.98	
2	−0.5	0	0			1	0.5	−0.5			0.57	0.30	0.99	
3	0	−0.5	−0.5			1	0.5	−0.5			0.50	0.28	0.98	
4	0	0	0			0.5	0	0			0.46	0.26	0.94	
5	0	0	0			1	0.5	−0.5			0.56	0.32	1.05	
6	0	−1	−1			1.5	−2	−2			0.60	0.40	1.28	(+)
7	0	−1	−0.5			0	0.5	0.5			0.51	0.27	0.93	
8	0	−0.5	0	−1	−1	3	1	−2	5	2	0.63	0.33	1.02	
9	0	0	0	0	−1	2.5	2	−0.5	1	4	0.60	0.33	1.06	
10	0	−1	−1	1	−2	2	0.5	−1.5	4	4	0.45	0.26	0.96	
11	0	0	0	0	0	1	2	1	1.5	2.5	0.65	0.34	1.04	
12	0	−1	0	−1	−1	0.5	0	−0.5	−4	0	0.46	0.30	1.11	
13	0	−0.5	0	0	−1	1	0	−1	−2	0	0.54	0.24	0.98	
14	0	−2	−2	0	−2	0.5	−1	−1	4	2	0.51	0.28	0.97	
15	0	−1	−1	0	0	3	2	−1	11	5	0.53	0.32	1.09	
16	0	0	0	0	0	1.5	1.5	0	3	3	0.44	0.27	1.01	
17	0	0	0	−1	−2	0	−2	−2	−3	−1	0.19	0.28	0.99	
18	0	−1	−1	0	−1	1.5	1	−0.5	6	2.5	0.49	0.29	1.03	
19	0	−1	−1	0.5	−1	1	0.5	−0.5	−3	1	0.49	0.27	0.95	
20	0	−1	−2	−0.5	−1	1.5	−1	−1.5	2	1	0.47	0.26	0.94	
21	0	−0.5	−0.5	1	−0.5	1	0.5	−0.5	5.5	1	0.51	0.28	0.97	
22	0	−1	−0.5	0	−1.5	0.5	1	−0.5	3	2	0.47	0.27	0.98	
23	0	−1	−2	−1	0	1	−2	−3	11	1	0.49	0.31	1.10	
24	0	0	0	1	0	0.5	2	1	4	4	0.47	0.31	1.12	

CR_2 was not flattened. The electrocardiograms taken twelve and twenty-four hours after successful operation showed progressive improvement.

In acute peritonitis, the electrocardiogram shows the pattern of coronary insufficiency consisted of depression of the ST segment, and the change returns to a normal pattern soon after a successful surgical treatment. The depression of the ST segment will be resulted from viscero-cardiac reflex caused by the stimulation due to peritonitis. However, in localized peritonitis, such as in acute appendicitis, the electrocardiogram shows almost no change. The deviation of the ST segement from base line correlated rather with severity of the illness than with the level of blood pressure.

The values of the deflection of the ST segment, amplitude of the T wave and the QT ratio observed in 24 patients are presented in Table 1. The relation between these components are presented in Table 2.

Table 2.

ST↓				12 (50%)
ST↓	+	T↓		4 (17%)
		T↓		3 (12%)
ST↓			+ U	1 (4%)
no remarkable change				4 (17%)
				24

ST↓ : depression of ST segment
T ↓ : lowering amplitude or inversion of T wave
U : appearance of U wave

The elevation of the QT ratio was observed in 4 patients, and all of them died in spite of adequate operation. The prominent U wave was observed in only one case. This abnormal prolongation of the QT was probably due to severe myocardial anoxia resulted from viscero-cardiac reflex.

2. The electrocardiogram in acute mechanical intestinal obstruction.

In acute mechanical intestinal obstruction, the electrocardiogram also shows a pattern of coronary insufficiency.

Case 1 (Fig. 3). U. T., a 67-year-old male. Diagnosis : Volvulus of small bowel. He suffered from nausea, vomiting and abdominal cramps for 20 hours before operation. The preoperative electrocardiogram showed marked depression of the ST segment with sinus tachycardia. The T waves were not flattened. At the time of operation, gangrenous small bowel was resected for about 3 meter length, and 400cc of citrated whole blood with 1500cc of physiologic saline solution was given. Several hours after the operation, marked improvement was observed in the electrocardiogram.

Case 2 (Fig. 4). T. H., a 54-year-old female. Diagnosis : Adhesive ileus due to peritonitis tuberculosa. She suffered from vomiting and abdominal cramps for 24 hours before operation. Depression of the ST segment without lowering amplitude of the T wave in lead CR_2 were observed in the preoperative electrocardiogram. However, after successful operation the electrocardiogram returned to normal. During operation, she received 800cc of whole blood with 1000cc of physiologic saline solution.

Table 3 and 4 show the value and the relation of the RS-T segment and the QT ratio observed in 12 patients. That is, the common change in aute intestinal obstruction is a depression of the ST segment, as in acute peritonitis. This change

Table 3. Electrocardiographic values in acute intestinal obstruction

upward deflection +mm
downward deflection −mm
mean value of QT ratio : 1.05

Patient No.	ST(deviation from base line)					T (amplitude)					RR	QT	QT ratio	U
	I	II	III	CR_2	CR_4	I	II	III	CR_2	CR_4				
1	−0.5	−1	−0.5			−2	−1	1			0.62	0.33	1.04	
2	0	−1	−1	0.5	−1	1	3	1.5	4	2	0.48	0.27	1.00	
3	−0.5	−2	−0.5	−2	−2	1	−1	−2	8	−2	0.40	0.25	0.98	
4	−0.5	−2	−1.5	0	−2	1	3	2	4	4	0.53	0.30	1.03	
5	−0.5	−0.5	0	−2	−2	0	−0.5	−0.5	7	1	0.57	0.32	1.05	
6	0	−1	−1	0	0	0.5	3	2	2	3	0.70	0.38	1.10	
7	0	0	0	0	0	2	2	0	2	3	0.48	0.28	1.01	
8	0	0	0	0	0	1	2	1	1	3	0.64	0.35	1.09	
9	0	0	0	1	−2	1	0	−1	1	1	0.85	0.40	1.08	(+)
10	0	−1.5	−1.5	−1	−1.5	1.5	−1	−2	3	1	0.55	0.33	1.10	
11	0	−0.5	−0.5	0	−2	2	3	1	10	6	0.56	0.30	1.00	
12	−0.5	−1	−0.5	0	−1.5	−0.5	2	1	2	2	0.52	0.32	1.09	

Table 4.

ST↓			6	(50%)
ST↓	+	T↓	3	(25%)
		T↓	2	(17%)
ST↓	+	T↓ + U	1	(8%)
			12	

usually returns to a normal pattern in a short time after a successful operation.

In chronic and mild intestinal obstruction, however, the electrocardiogram usually shows no or a slight change. The following case report is offered to illustrate the electrocardiographic change in chronic intestinal obstruction.

Case 3 (Fig. 5). K. Y., a 48-year-old male. Diagnosis : Chronic adhesive ileus. Although he suffered from nausea and abdominal pain, his condition was not so disturbed. The electrocardiogram was taken on 3rd, 5th, and 8th days after onset of the illness. There were no remarkable change in electrocardiogram except slight increase in the T wave.

3. The electrocardiogram in circulatory collaps due to hemorrhage.

In surgery, patients are always exposed to bleeding in various degrees, and it is well known that the circulatory collaps indicates certain electrocardiographic changes. In relation to the postoperative electrocardiographic changes, the influence of circulatory collaps was investigated.

Case 1 (Fig. 6). S. A., a 42-year-old male. Diagnosis : Gastric ulcer. He was admitted to the surgical division under shock syndrom due to massive hematemesis. The blood pressure was 55/35mmHg, the red cells were 2.7 million and the percentage of hemoglobin was 58. (A) was taken before treatment (4.50 p. m.). The ST segment depressed, however the T wave was tall and peaked. (B) was taken after 400cc of blood transfusion and the blood pressure rose up to 94/40mmHg (5.35 p. m.), (C) was taken at 6.50 p. m., at which time the total volume of

blood transfused became 800cc. The blood pressure rose up to 100/30mmHg, and the ST segment progressively returned to normal level.

Case 2 (Fig. 7). K. A., a 55-year-old male. Diagnosis : Carcinoma of the rectum. He was in shock due to massive hemorrhage which occured immediatly after radical operation for carcinoma of the rectum. (A) was taken two weeks before operation. The blood pressure was 115/70 mmHg. (B) was taken during shock syndrome, the blood pressure fell to 76/70mmHg. Marked depression of the ST segment with sinus tachycardia was observed, on the other hand, the T wave became taller than preoperative T wave.

Case 3 (Fig. 8). T. N., a 34-year-old female. Diagnosis : Gastric ulcer. She was in shock due to bleeding from the operative wound. (A) was taken two days before operation, and the blood pressure was 102/74mmHg. (B) was taken during circulatory collaps, and the blood pressure fell to 80/75mmHg. Although the ST segment depressed remarkably with sinus tachycardia, the T wave became taller and peaked. (C) was taken after 800cc of blood transfusion, the blood pressure rose up to 112/55mmHg and the ST segment returned to normal with lowering of the T wave.

As illustrated in above cases, the electrocardiograms showed severe coronary insufficiency during circulatory collaps, and these changes returned to a normal configuration rapidly after sufficient blood replacement.

Table 5. Electrocardiographic values in circulatory collaps

upward deflection +mm
downward deflection −mm
mean value of QT ratio : 1.01

Patient No.	ST (deviation from base line)					T (amplitude)					RR	QT	QT ratio	U	blood pressure
	I	II	III	CR_2	CR_4	I	II	III	CR_2	CR_4					
1	0	−2	−2			2	3	1			0.41	0.27	1.05		75/54
2	0	0	0			1	1	0			0.42	0.26	1.00		imp.
3	−0.5	−0.5	0			−0.5	−0.5	0			0.45	0.25	0.92		105/95
4	0	−0.5	−0.5			1	4	3			0.36	0.22	0.91		65/45
5	0	−2	−2	−3	−3	1	3	2	11	9	0.52	0.32	1.09		96/70
6	0	−1	−1	−2	−1	0.5	1	0.5	5	2	0.45	0.27	1.00		98/96
7	0	−1	−0.5	−0.5	1	1	0.5	−0.5	4	3	0.57	0.32	1.05		70/50
8	0	−1	−0.5	−0.5	1	1	2	1	13	7	0.41	0.26	1.01		80/75
9	0	−0.5	0	1	0	1	3	2	4	4	0.54	0.31	1.05		38/0
10	0	−1	−1	−1	−2	0.5	4	4	8	8	0.60	0.35	1.12		55/35
11	0	−1	−1	0	0	0.5	−1.5	−1.0	0	1	0.66	0.34	1.03		95/85
12	−0.5	−2	−3	−1	−4	2		2	12	9	0.44	0.27	1.00		58/30
13	0	−1	−1	0	−2	0.5	3	2	8	4	0.41	0.25	0.97		imp.

imp. : impossible to measure.

Table 6.

ST↓	12 (92%)
ST↓ + T↓	1 (8%)
	13

Table 5 and 6 show electrocardiographic manifestations which were observed in circulatory collaps. The tall and peaked T wave in precordial leads, which

has been called "asphyxiating T wave", was found in 6 out of 9 cases.

4. The electrocardiographic changes after gastrectomy.

The electrocardiograms in acute intestinal obstruction, acute diffuse peritonitis, and circulatory collaps were described above, and the changes were consisted of depression of the ST segment with relatively slight change in the T wave. The patients, who received gastrectomy, sometimes complained of nausea, vomiting, abdominal distension, muscular weakness, dyspnea etc. postoperatively and their recovery were disturbed. These symptoms were considered to be quite functional and the electrocardiogram showed distinctive changes during the period of these distress.

In this surgical division, customarily, food is withheld for 48 hours after gastrectomy. During this period, 100cc of whole blood and 500cc of RINGER's solution with 500cc of 5% glucose solution are administered daily.

The serial electrocardiograms were recorded in 84 patients after gastrectomy and the significant electrocardiographic changes were observed in 27 patients. On the other hand, 25 patients complained of vomiting, generalized muscular weakness or abdominal distension postoperatively and the significant electrocardiographic changes were observed in all of them.

That is to say, the postoperative electrocardiographic changes were closely related with postoperative clinical symptoms, and these changes had a tendency to return to normal as soon as the patient began oral feeding. Case reports are illustrated to show how the electrocardiographic changes are related with the postoperative clinical course.

Case 1 (Fig. 9). H. Y., a 24-year-old male. Diagnosis : Gastric ulcer. In this case, the postoperative clinical course was quite uneventful and the serial electrocardiograms also showed no change.

Case 2 (Fig. 10). R. M., a 57-year-old male. Diagnosis : Duodenal ulcer. His postoperative clinical course was disturbed by nausea and abdominal distension and electrocardiogram showed lowering amplitude of the T wave. These clinical symptoms such as nausea, abdominal distension and generalized muscular weakness gradually increased untill he took a meal on the 3rd postoperative day, then the lowered amplitude of the T wave returned to a normal configuration with good clinical improvement. The change in the serum potassium concentration was slight.

Case 3 (Fig. 11). Y. N., a 22-year-old male. Diagnosis : Gastic ulcer. 42 hours after gastrectomy, he complained of nausea, vomiting and generalized musclar weakness and the electrocardiogram showed a depressed ST segment with lowering amplitude of the T wave. However, when he began to take a meal, the electrocardiographic changes returned to normal on the 3rd postoperative day.

Case 4 (Fig. 12). Y. S., a 48-year-old female. Diagnosis : Gastric ulcer. She complained of persistent anorexia, abdominal distension and muscular weakness after gastrectomy, and the serial postoperative electrocardiographic tracings showed progressive lowering amplitude of the T wave with appearance of the prominent U wave. On the 8th and 9th postoperative days, 3g of potassium chloride was

administered by mouth because her distress progressed in spite of routine therapy. On the 10th postoperative day, the electrocardiographic abnomalities disappeared and she had good appetite.

Case 5 (Fig. 13). Y. K., a 28-year-old female. Diagnosis : Gastric ulcer. Twenty-four hours after gastrectomy, she had fatigue and was lethargic. She began to vomit frequently and complained of dyspnea and insomnia on the 2nd postoperative day. On the 3rd day, her condition appeared critical, and the electrocardiogram showed flattening and inversion of the T waves with prominent U waves. Although the serum potassium level at this time was 6.0mEq./L., 2g of potassium chloride was given by mouth, and dramatic improvement occurred within an hour. On the 4th day, her condition appeared satisfactory and the electrocardiogram gradually returned to a normal configuration.

In case 4 and 5, the postoperative distress and the electrocardiographic changes were severe, and the administration of potassium chloride only seemed to be able to improve them.

As illustrated in above cases, the postoperative electrocardiographic changes are closely connected with the clinical conditions. These electrocardiographic changes are discussed in detail.

a) P wave : Nine out of 84 patients (11%) showed an increased amplitude of the P wave in Lead II and III, which are known as pulmonary P wave. This change, accompanying with the inversion of the T wave in CR_2, may be the results of the right atrial and right ventricular strain caused by respiratory disturbance due to pain of wound.

b) RS-T segment ; The lowering amplitude or the inversion of the T wave, especially in Lead II or CR_1, is the most frequent and significant change. This change was observed in all 27 cases, and depression of the ST segment was accompanied in only 6 of them (24%).

c) U wave and QT prolongation ; The appearance of the prominent U wave is also significant, and was observed in 17 out of 27 patients (63%). The QT prolongation, calculated from the Bazett's formula as QT ratio, was observed in 15 out of 27 patients (55%).

The correlation between these electrocardiographic changes are presented in Table 6 and 7.

After all, the electrocardiographic changes after gastrectomy are able to be represented by lowering amplitude or inversion of the T wave with appearance of the prominent U wave.

These changes show quite different appearance from the features observed in generalized peritonitis, acute mechanical intestinal obstruction and circulatory collaps.

For example, two case reports are offered to illustrate these conditions.

Case 6 (Fig. 14). M. O., a 41-year-old male. Diagnosis : Gastric cancer. He suffered from persistent vomiting after subtotal gastrectomy with muscular weakness. However, serial postoperative electrocardiograms showed no specific change in

Table 6. Electrocardiographic values in gastrectomy

upward deflection +mm
downward deflection −mm
mean value of QT ratio : 1.12

Patient No.	ST (deviation from base line) I	II	III	CR_2	CR_4	T (amplitude) I	II	III	CR_2	CR_4	RR	QT	QT ratio	U	Serum K mEq./L.
1	0	0	0			0.5	0.5	0.5			0.67	0.42	1.28		
2	0	0	0			2	1	−1			0.71	0.31	1.04	(+)	
3	0	0	0			0.5	1	0.5			0.60	0.34	1.09		
4	0	0	0			1.5	1.5	0			0.70	0.38	1.13		
5	0	0	0			1		−0.5			0.66	0.39	1.20		
6	−0.5	−1	−0.5			0.5	0.5	−0.5			0.73	0.40	1.17	(+)	
7	0	0	0			1	−0.5	−0.5			0.70	0.37	1.10		
8	0	0	0			0	0.5	1			0.95	0.55	1.40		
9	0	0	0			0.5	1	1			0.71	0.36	1.06	(+)	
10	0	0	0			0.5	1.5	0.5			0.68	0.35	1.06	(+)	
11	0	0	0	0	0	0.5	1	0	0.5	0.5	0.69	0.35	1.08		
12	0	0	0	0	0	1	0	0	0	3	0.69	0.38	1.05		
13	0	0	0	0	−1	0.5	1	0	−2	−2	0.65	0.37	1.14	(+)	
14	0	0	0	0	−1	0.5		−0.5	5	5	0.74	0.37	1.08		4.1
15	0	0	0	0	−1	0.5		0.5	0.5	4	0.69	0.38	1.14	(+)	3.3
16	0	−1	−1			1.5	0.5	−1			0.67	0.32	0.96	(+)	4.0
17	0	0	0			1	0.5	−0.5			0.72	0.35	1.02		3.7
18	0	0	0	0	−1	1	−1	−1.5	1	1	0.61	0.37	1.17	(+)	6.0
19	0	0	0			2	1	0			0.78	0.38	1.05	(+)	3.6
20	0	0	0	0	0	1	0.5	−0.5	−1	2	0.90	0.41	1.07	(+)	3.8
21	0	0	0			1.5	1	0.5			0.83	0.42	1.15	(+)	4.4
22	0	−0.5	0	0	−1	0.5	−1	−1	0.5	0.5	0.67	0.38	1.16	(+)	3.5
23	0	0	0	0	−1	0	0.5	0.5	4	2	0.90	0.43	1.12	(+)	3.2
24	0	−1.5	−1	2	0	0.5	3	2	2	4	0.80	0.40	1.12	(+)	4.7
25	0	−1	−1	−1	−1	1	1.5	0.5	6	3	0.60	0.33	1.05	(+)	3.5
26	0	−1	0	−1	0	0.5	1	−1.5	4	4	0.78	0.41	1.15	(+)	4.2
27	0	0	0	0	−0.5	1	2	1	1.5	3	0.62	0.36	1.13	(+)	4.0

Table 7.

	T↓	+	U	11 (41%)
	T↓			10 (37%)
ST↓	+ T↓	+	U	6 (22%)
				27

the T wave. Postoperative vomiting and muscular weakness of this patients were resulted not from potassium depletion but from mechanical obstruction of gastro-enteric anastomosis. The differential diagnosis was easily determined by electrocardiogram.

Case 7 (Fig. 15). A. F., a 51-year-old male. Diagnosis : Duodenal ulcer. Although he was allowed to take food on the 3rd postoperative day, the electrocardiogram showed low or inverted T wave and depression of the ST segment. However, the T wave in CR_2 showed high amplitude, showing a different attitude from the change descreibed above. On the 7th postoperative day, he was diagnosed as peritonitis and laparotomy was performed.

On the other hand, as illustrated in case reports, these electrocardiographic changes seemed to have a tendency to be correlated with postoperative starvation. If these patients could take food soon after operation, a lesser electrocardiographic change would appear. To clarify this question, the serial electrocardiograms were recorded after operation for carcinoma of the rectum, because the patient can take food on the second postoperative day in this operation.

5. The electrocardiogram after operation for carcinoma of the rectum.

In this surgical division, a permanent colostomy was done about a week before radical operation, so the patient can take food on the 1 st postoperative day. The following case report is illustrated to show electrocardiographic changes after radical operation for carcinoma of the rectum.

Case (Fig. 16). K. N., a 48-year-old female. Although depression of the ST segment with lowering amplitude of the T wave and sinus tachycardia were observed soon after operation, these changes gradually returned to normal postoperatively. During operation, there was relatively large bleeding and blood pressure was unstable. For this reason, the postoperative electrocardiographic changes of this patient were considered to be the coronary insufficiency due to bleeding. She took diet on the 2nd postoperative day and her condition appeared satisfactory.

In 16 patients who received combined abdominoperineal resection, progressive lowering amplitude of the T wave was not observed. The different attitude of the postoperative electrocardiographic change between gastrectomy and this operation may be resulted from the fact that the period of starvation is longer in former operation. The changes caused by anesthesia or bleeding return to normal with routine therapeutic procedure.

The postoperative electrocardiogram after gastrectomy shows quite different changes from obtained in acute circulatory failure or severe peritoneal stimulation. The changes observed in this study became progressively prominent on the 2nd or 3rd postoperative day, accompanying some clinical findings.

Eliel and coworkers reported that the certain electrocardiographic changes in association with the low serum potassium level were observed in postoperative patients with longstanding electrolyte disturbances. Lans and associates described that the symptoms in patient with potassium depletion were characterized by nausea, anorexia, muscular weakness, abdominal distension and mental confusion. The electrocardiographc patterns have been described in association with hypopotassemia and considerable confusion exists because of the various patterns observed in different patients. However, as presented in Table 6, no lowering of the serum potassium level was observed in our cases.

The electrocardiogram of potassium depletion can be observed with normal serum potassium concentration, on the other hand, these electrocardiographic changes and clinical symptoms were remarkably reduced by preventive administration of potassium chloride. That is, 1.5g of potassium chloride was administered on the 1 st postoperative day in 24 patients who received gastrectomy, and only 2 patients (8%) showed these findings. This fact shows the close relation between the electrocardiographic changes and potassium metabolism.

To clarify these problems, the electrocardiographic patterns and the serum potassium concentration in the patients who showed clinical syndrome of potassium depletion were studied in detail.

6. The electrocardiogram and the serum potassium concentration in the patients who showed the clinical syndrome of potassium depletion.

The electrocardiographic changes were studied in 28 patients who showed the symptoms of potassium depletion and were dramatically improved by administration of potassium chloride only.

The following case reports are presented to illustrate these electrocardiographic patterns.

Case 1 (Fig. 17). M. M., a 65-year-old male. Diagnosis : Carcinoma of the esophagus. He had longstanding diarrhea due to administrating nourishing fluid through jejunostomy, and complained of muscular weakness, shallow respiration and lethargy. Although the electrocardiogram taken before treatment showed inversion or lowering amplitude of the T waves with the U waves, the serum potassium was 4.3mEq /L., which was normal level. Two hours after administration of 1g of potassium chloride through jejunostomy, the T waves increased its amplitude and the U waves became less prominent. His condition seemed quite satisfactory after 24 hours and 3g of potassium chloride was administered, and the electrocardiogram returned to almost normal configuration. No remarkable change was observed in the serum sodium concentration during treatment.

Case 2 (Fig. 18). T. M., a 25-year-old female. Diagnosis : Gastroptosis. She suffered from persistent vomiting from unknown origin for 5 months. Her electrocardiogram showed inversion of the P waves and lowering amplitude of the T waves. Although serum potassium level was within normal limits (4.8mEq./L.), the potassium depletion was called questionable.

After 5g of potassium chloride was given in 24 hours, increased amplitude of the T waves was observed and vomiting diminished. The serum potassium level then was 4 8mEq./L. The electrocardiogram returned to normal pattern except inversion of the P waves in limb leads on the 3rd day after the beginning of the treatment, and she never complained of vomiting.

Case 3 (Fig. 19). T. N., a 34-year-old female. Diagnosis : Chronic intestinal obstruction. She had a history of diarrhea and vomiting for 7 days, and complained of severe mascular weakness. The electrocardiogram showed inversion of the T waves with the depressed ST segment, and the serum potassium level was 4 0mEq. /L. which was within normal range (A). However, one hour following administration of 1g of potassium chloride by mouth, the T waves became upright with disappearance of the ST depression (B). The serum potassium level was 4.4mEq. /L. Muscular weakness and vomiting diminished, and she had good appetite.

As illustrated in the above cases, the electrocardiographic changes and clinical symptoms in potassium depletion return to normal following administration of potassium chloride.

Table 8. Electrocardiographic values in the patients with clinical syndrome of potassium depletion

upward deflection +mm
downward deflection −mm
mean value of QT ratio : 1.16

Patent No.	ST(deviation from base line)					T (amplitude)					RR	QT	QT ratio	U	Serum K mEq./L.
	I	II	III	CR_2	CR_2	I	II	III	CR_2	CR_4					
1	0	0	0			−1	−1	0			0.93	0.48	1.24	(+)	
2	0	0	0			2	2	0			0.68	0.36	1.09		
3	0	0	0			0	2	2			0.93	0.58	1.50		
4	0	0	0	−1	0	1.5	1	0.5	−1	1	0.60	0.34	1.09	(+)	
5	0	0	0	0	0	1	0.5	−0.5	1.5	1.5	0.78	0.38	1.07	(+)	
6	0	0	0	0	0	0.5	0	−0.5	2	2	0.65	0.37	1.14	(+)	
7	0	0	0	0	0	0	0.5	0.5	0.5	1	0.69	0.38	1.14		
8	0	−1	−0.5	0	−1.5	0	−1	−1	0	−1	0.67	0.28	1.16	(+)	
9	0	0	0	0	0	2	0.5	−1.5	2	2.5	0.68	0.37	1.12		
10	0	0	0	1	0	1	1	0	1.5	2	0.58	0.34	1.11		
11	0	0	0	0	0	1	1	0	1	2	0.90	0.43	1.12	(+)	
12	0	0	0	0	0	0	0	0	1	0	0.52	0.33	1.14		
13	0	−0.5	0.5	−0.5	−1	0.5	0.5	0	−1.5	0.5	0.58	0.38	1.25		3.8
14	0	0	0	−0.5	−0.5	3	1	−1.5	−7	2	0.58	0.38	1.25		3.6
15	0	0	−1	−0.5	0	1	−1	−1.5	−2	0	0.61	0.35	1.12	(+)	4.0
16	0	0	0	0	0	0	−1	−1	0	−2	0.63	0.35	1.10	(+)	3.5
17	0	0	0	0	0	0.5	0.5	0	1	1.5	0.85	0.40	1.10		4.1
18	0	0	0	0	−1	0	1	1	5	2	0.90	0.43	1.12	(+)	3.2
19	0	−2	−2	2	−1	1.5	2	2	2.5	5	0.80	0.40	1.12	(+)	4.7
20	0	−1	−1	−1	−2		1.5	0	6	4	0.60	0.33	1.05	(+)	3.5
21	0	0	0	0	0	1	−0.5	−1.5	2	3	0.80	0.40	1.12	(+)	4.2
22	0	0	0	0	−1	0	1	1	5	0.5	0.65	0.38	1.17		3.6
23	0	0	0	0	0	1	1.5	0.5	1.5	1	0.63	0.36	1.12	(+)	4.4
24	0	0	0	0	−0.5	0	0.5	0.5	0.5	−1	0.65	0.40	1.24	(+)	4.4
25	0	0	0	0.5	−1.5	1	1.5	0.5	2.5	1.0	0.90	0.48	1.25	(+)	3.5
26	0	0	0	0	0	0	−1	−1	1	1	0.76	0.40	1.15	(+)	4.3
27	0	−0.5	−0.5	−1	−2	1.5	1.5	0	2.5	2	0.45	0.35	1.31		4.9
28	0	0	0	0	0	1	0.5	−0.5	2	1.5	0.51	0.32	1.11		4.5

Table 9.

	T↓	+	U	12 (43%)
	T↓			11 (40%)
ST↓	+ T↓	+	U	2 (7%)
ST↓		+	U	2 (7%)
ST↓	+ T↓			1 (3%)
				28

The electrocardiographic values in 28 patients showing a syndrome of potassium depletion, are presented in Table 8. The combination between the changes in the ST segment, the T wave and the U wave is presented in Table 9. The low amplitude of the T wave with the appearance of the U wave seemed to have close correlation with the potassium depletion.

Figure 20 shows the illustrative examples of the progressive changes in precordial lead CR_4 observed in 28 patients with potassium depletion.

The serum potassium was determined in 16 patients, and data also failed to show any consistent correlation between the electrocardiogram and the serum potassium concentration. That is to say, the electrocardiogram has an excellent diagnostic value than the determination of the serum concentration in potassium depletion.

In this respect, several authors have stressed the lack of conformity of electrocardiographic manifestations with the serum potassium levels. This disparity has been attributed to the presence of electrocardiographic alterations from other causes or to concomitant abnormalities of other electrolytes. For example, ROBERTS and MAGIDA studied the influence of the acid-base balance experimentally and concluded that electrocardiographic changes suggesting hypopotassemia were dependent upon the pH rather than the actual serum potassium concentration. TARAIL, on the other hand, was unable to establish any correlation between serum pH, sodium, or calcium with the intensity of potassium effects reflected in clinical electrocardiograms. CRISMON and his associates could not relate the intracellular potassium concentration to a typical electrocardiographic events in hypopotassemia. BELLET also, could not establish a definite relationship of the electrocardiographic changes to skeletal muscle potassium content. His comparisons with the electrocardiogram gave no better results than serum potassium concentration alone. KÜHNS, on the other hand, noted such a relationship in animal experiments. In relating intracellular/extracellular potassium concentrations he used a value termed "cardiac potassium quotient" with a normal range of 25 to 32. Elevation of this quotient was associated with typical hypopotassemic changes in the electrocardiogram. There was, however, no consistency between the electrocardiographic alterations and absolute potassium or sodium concentrations, intracellular or extracellular.

In order to clarify the correlation between the electrocardiogram and the actual serum potassium concentration by determining its intracellular/extracellular relationship, attempts were made experimentally using the method which KÜHNS had reported in 1955.

7. The electrocardiogram and "cardiac potassium quotient"

Experimentally, potassium depletion was produced by following method. Using mongrel dogs, gastrectomy was performed and DOCA was administered postoperatively. The serial electrocardiograms (standard and precordial leads) were recorded. The serum potassium concentration and the intracellular/extracellular relationship in heart muscle were determined by following formula.

1) $\frac{\text{extracell. muscle water (in g/kg dry subst.)}}{} = H_2Oe/kg = \frac{Clmd.}{Cls.} \cdot \frac{1000}{1.04}$

2) $\frac{\text{intracell. muscle water (in g/kg dry subst.)}}{} = H_2Oi/kg = H_2Omd/kg - H_2Oe/kg$

3) $\frac{\text{extracell. muscle - K - content (in mEq/kg dry subst.)}}{} = Ke/kg = (Ks.\ 0.95) \cdot \frac{H_2Oe/kg}{1000}$

4) $\frac{\text{extracell. muscle - K - conc. (in mEq/L extracell. water)}}{} = Ks.\ 0.95$

5) $\frac{\text{intracell. muscle - K - content (in mEq/kg dry subst.)}}{} = Ki/kg = Kmd/kg - Ke/kg$

6) $\frac{\text{intracell. muscle - K - conc. (in mEq/L intracell. water)}}{} = Ki/L = \frac{Ki/kg}{H_2Oi/kg} \cdot 1000$

7) cardiac potassium quotient $= \frac{\text{intracell.}}{\text{extracell.}}$ K-concentration

Clmd = Cl in total muscle in mEq/kg dry substance

Cls = Cl in serum in mEq/L

The normal range of the serum potassium in 20 dogs was from 3.2 to 4.7 mEq./L. with an average value of 4.0mEq./L. In 5 normal dogs, the intracellular potassium concentration of left ventricular myocardium was 97.0 to 115.0mEq./L. with an average value of 101.9mEq./L. and the extracellular was 3.07 to 4.06mEq./L. with an average value 3.3mEq./L. Total potassium content was 290 to 322mEq./kg. with an average value 308mEq./kg. The cardiac potassium quotient lay between 25.9 and 32 1. Elevation of this quotient was observed in potassium depletion.

In Figure 21, although the serum potassium level decreased from 3.5 to 2.9 mEq./L. postoperatively, the electrocardiogram showed no significant changes, and the animal's condition seemed to be quite well. The total potassium content in heart muscle was normal. The cardiac potassium quotient was 29.3 in spite of low intracellular and extracellular potassium concentration.

In Figure 22, no electrocardiographic change with low serum potassium level (2.8mEq./L.) was also observed. The total potassium content in heart muscle slightly decreased. The cardiac potassium quotient was in normal range (28.1), but the intracellular and extracellular potassium concentration were both decreased.

In figure 23, on the other hand, the electrocardiographic change was observed with slightly low serum potassium level (3.1mEq./L.). The amplitude of the T wave lowered with wide base. The cardiac potassium quotient then elevated to 41.6. The total potassium content in the heart muscle and the intracellular potassium concentration were slightly increased and the extracellular potassium concentration was slightly decreased.

In Figure 24, the electrocardiographic change was observed with low serum potassium concentration (2.4mEq./L.). The cardiac potassium quotient also elevated to 41.3. The total potassium content in heart muscle was normal, although the intracellular and the extracellular concentration were decreased.

The electrocardiographic changes induced in this experiment also returned to a normal configuration following administration of potassium chloride by mouth, illustrating in Figure 25. Thus, as KÜHNS described in his paper, the electrocardiographic change in potassium depletion seems to have a good correlation rather with the cardiac potassium quotient than the serum potassium concentration.

The results of animal experiment show that the typical electrocardiographic changes are observed with normal serum potassium concentration in potassium depletion, and, on the other hand, no changes can be observed with low concentration. That is, the imbalanced relationship between intra- and extracellular potassium concentration in heart muscle resulted from potassium depletion can cause change in the electrocardiogram.

DISCUSSION

The significant electrocardiographic changes, concerning with the changes of

the T wave, the ST segment and the U wave, were observed frequently following gastrectomy.

Ruf, Rösch & Walz reported that the changes of the ST and the T wave observed after gastrectomy had appeared with tachycardia, so these changes did not mean myocardial damage. They considered tachycardia was induced by psychic influence of patient, by anesthesia, by surgical procedure, or viscero-cardiac reflex and they noted that the strain of sympathetic nerve was chief cause of electrocardiographic changes. Buhr, however, neglecting such factors, considered that these changes suggested myocardial damage brought by the effect of anesthetic agent and operative procedure. Shimizu also described that the changes represented myocardial damage caused by anesthesia, by acute circulatory insufficiency due to bleeding and by viscero-cardiac reflex. Certainly, the electrocardiograms taken immediatly after operation may show myocardial damage caused by many factors described above. However, as Buhr described, these changes have a tendency of returning to the normal pattern postoperatively. On the contrary, the changes observed in this study became more prominent progressively after operation with clinical findings. Moreover, as described before, the electrocardiographic features in viscero-cardiac reflex or in circulatory disturbance are quite different from the changes obtained in this study.

Recently, it has been known that the surgical trauma causes increased production of ACTH, which stimulates the adrenal cortex and results in renal loss of potassium. In addition, loss of gastrointestinal secretion, malnutrition, large intake of sodium chloride may result potassium depletion postoperatively. Therefore, the postoperative electrocardiogram may possibly show the changes which reflect potassium depletion. However, there are many opinions in the correlation between electrocardiographic changes and potassium depletion.

Ringer has pointed the important relationship between muscular contractility of the heart and potassium. Change in potassium metabolism will later the sequence of events in the heart, causing conspicuous alterations in electrocardiogram. Orent-Keiles and McCollum demonstrated that rats on very low potassium diets showed reduced potassium content of the heart muscle and necrosis. Pearson and his coworkers obtained electrocardiogram from potassium deficient rats that exhibited lowered amplitude of the T wave and interference with auriculo-ventricular conduction. Darrow and his coworkers observed that rats showed myocardial necrosis after serial injection of DOCA. Hench and Sommervill obtained electrocardiogram from potassium deficient rats that exhibited lowered amplitude of the T wave interference with auriculo-ventricular conduction. They also obtained electrocardiogram from patients received Cortison therapy, exhibiting the abnormal T wave, and prolongation of the PR, QT intervals. However, they did not consider that these changes were resulted from potassium depletion. Reeder suggested that the electrocardiographic changes observed during ACTH and Cortison therapy had correlation with serum potassium level. Yoshitoshi, using DOCA in animal experiment, reported that the electrocardiogram changed in low serum potassium level. Martin, Bellet and Nadler observed that the electrocardiogram and the

serum potassium level were related closely in hypopotassemic condition.

On the other hand, CURRENCE and LJUNGGREN reported that no relationship was observed between the electrocardiogram and serum potassium level during ACTH, DOCA or Cortison therapy. SCHWARTZ concluded that in potassium depletion of moderate severity the electrocardiogram could not be relied upon as a guide to diagnosis or therapy. He also concluded that the electrocardiogram was consistently related neither to the total potassium deficit nor to the serum potassium concentration. LANS and his coworkers, studying potassium deficiency in surgical patients, emphasized that the electrocardiographic changes did not appear consistently at specific serum potassium level.

In this study, the data demonstrated that the electrocardiogram was quite reliable as an index to reflect the potassium depletion and could be relied upon as a guide to diagnosis or therapy. However, the serum potassium concentration failed frequently to reflect even moderately large loss of potassium. The actual level of the serum potassium may be misleading because if dehydration and hemoconcentration are present, and the serum potassium level may be normal or even slightly increased, despite of abnormally disturbed potassium metabolism. In animal experiment, the electrocardiogram showed definite relationship to cardiac potassium quotient, and there was no consistency between electrocardiographic changes and absolute potassium concentrations, intracellular or extracellular.

After all, the most important things to make a correct diagnosis of potassium depletion by electrocardiogram after gastrectomy is to record serially and analyse the changes in association with clinical findings.

However, as to the electrocardiographic criteria, it should be noted that similar changes may be observed in certain other clinical states. Among these are myocardial abnormality or disease, myocardial anoxia, the effect of drugs, but the differential diagnosis can be made in most instances from the history and physical examination.

SUMMARY

Following gastrectomy, the serial electrocardiographic recordings often showed lowering amplitude or inversion of the T wave and appearance of the U wave. These changes were frequently accompanied with clinical manifestations of anorexia, nausea, vomiting, muscular weakness and abdominal distension, all of which return to normal upon administration of diet or potassium chloride. However, the serum potassium concentration failed to reflect postoperative potassium depletion. These electrocardiographic patterns and the serum potassium levels were studied and analised also in the patient with the clinical syndrome of potassium depletion. In animal experiment, the electrocardiogram showed more definite relation to cardiac potassium quotient than serum potassium level. The postoperative serial electrocardiogram could be relied upon as a guide to diagnosis or therapy of potassium depletion especially after gastrectomy.

The author wishes to thank Dr. T. SHIOTA and Dr. T. KASHII for kind guidance in the determination of potassium.

Outlines of this study were reported at the annual meeting of Japanese Circulation Society in 1953.

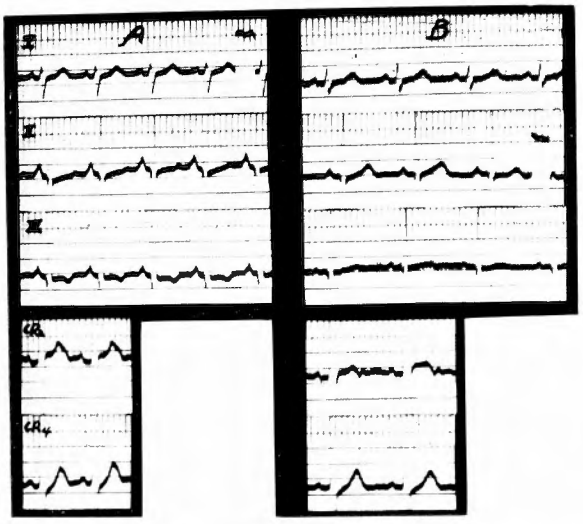


Fig. 1. Case 1. Sinus tachycardia and depression of ST segment associated with acute generalized peritonitis.

A. Before operation. Pulmonary P wave is observed in this case. Blood pressure : 85/50 mmHg.

B. 12 hours after operation. Note marked improvement in leads II and III. Blood pressure : 100/6 5mmHg.

Fig. 2. Case 2. Note progressive improvement after successful operation for acute peritonitis. A. Before operation. T wave in lead CR_2 is not flattened in this case. B. 12 hours after operation. C. 24 hours after operation.

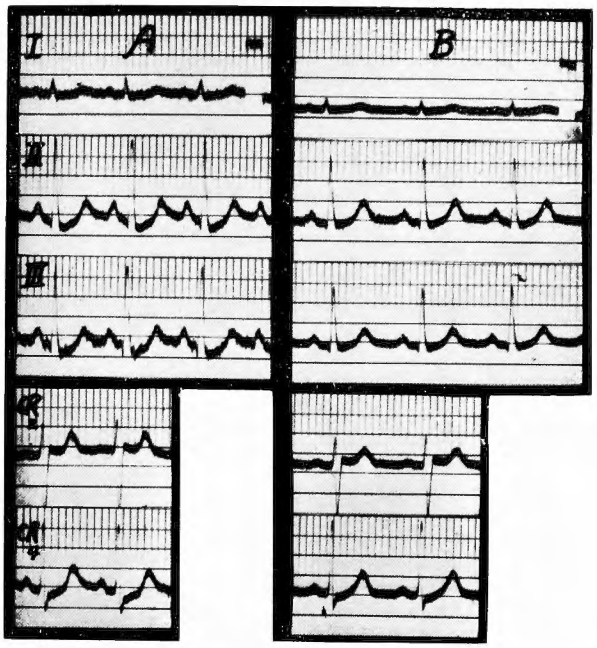


Fig. 3. Case 1. Sinus tachycardia and marked depression of ST segment in leads Ⅱ, Ⅲ and CR_4 associated with acute mechanical intestinal obstruction. A. Before operation. Blood pressure : 104/74 mmHg. B. Several hours after resection of gangrenous small bowel. Blood pressure : 108/74 mmHg.

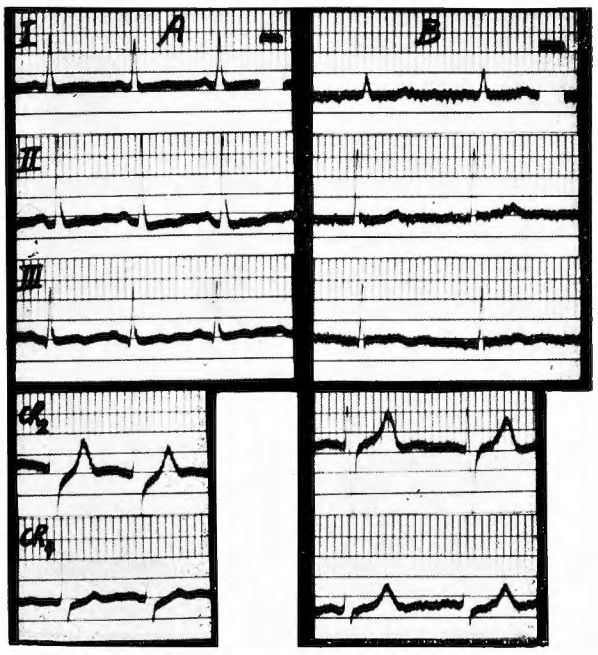


Fig. 4. Case 2. Acute mechanical intestinal obstruction.
A. Before operation. Note ST depression in leads Ⅱ, Ⅲ, CR_2 and CR_4.
B. 3 hours after operation.

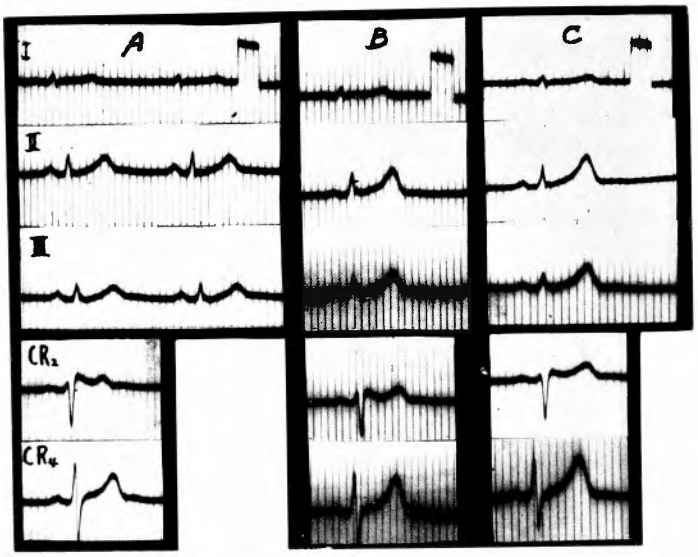


Fig. 5. Case 3. Slight electrocardiographic change in chronic intestinal obstruction. A. 3 days, B. 5 days, C. 8 days after onset of illness. T wave in leads Ⅱ, Ⅲ and CR_1 progressively increased.

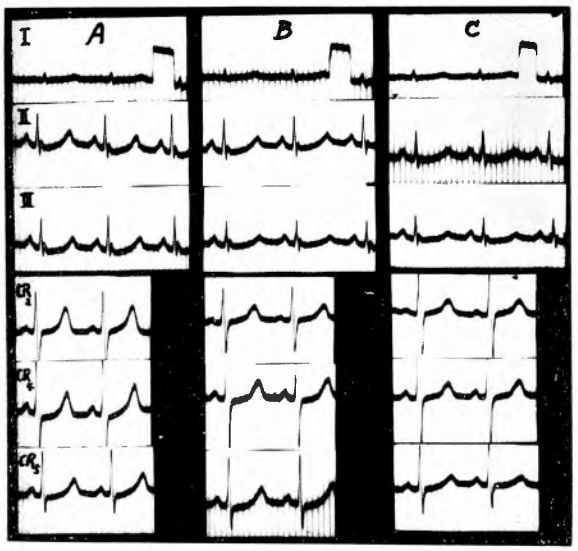


Fig. 6. Case 1. ST depression with tall and peaked T wave in association with hemorrhagic shock.

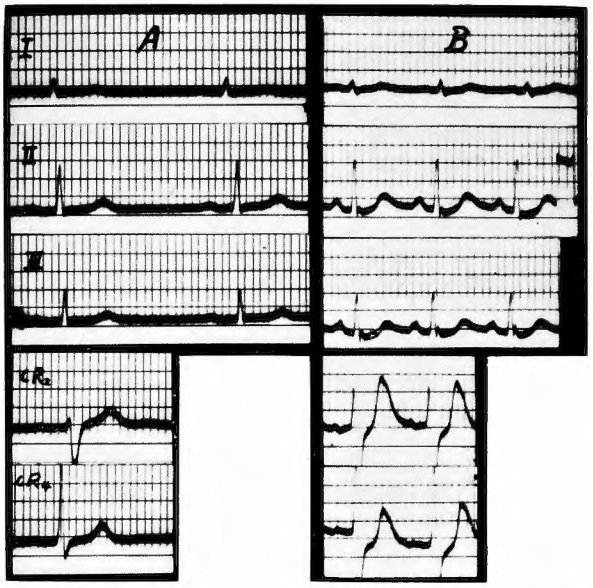


Fig. 7. Case 2. Note marked depression of ST segment in leads Ⅱ, Ⅲ, CR_2 and CR_4 and tall peaked T wave called "asphyxiating T wave" in leads CR_2 and CR_4 in association with hemorrhagic shock.

A. 2 weeks before operation.

B. During shock state.

Fig. 8. Case 3. Hemorrhagic shock.

A. 2 days before operation. Blood pressure : 102/74 mmHg.

B. During shock state. Blood pressure : 80/75 mmHg.

C. After blood transfusion. Blood pressure : 112/55 mmHg.

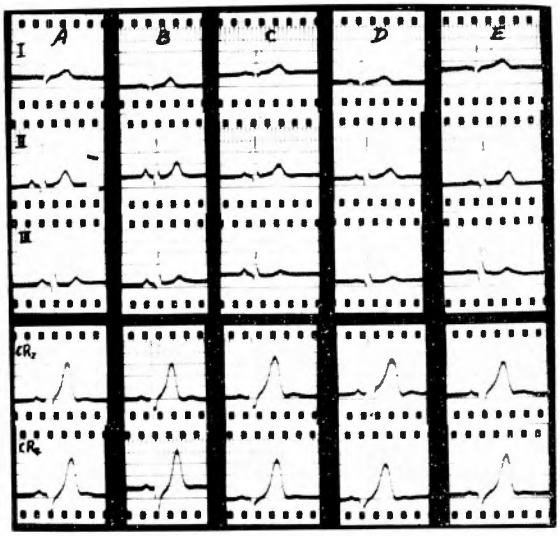


Fig. 9. Case 1. Serial electrocardiograms after gastrectomy with uneventfull clinical course. A. 2 days before operation. Serum K : 3.7mEq./L. Serum Na : 138 mEq./L. B. Several hours after operation. C. 24 hours. D. 48 hours. Serum K : 3.5mEq./L. serum Na : 140mEq./L. E. 72 hours. Serum K : 4.0mEq./L. Serum Na : 140mEq./L.

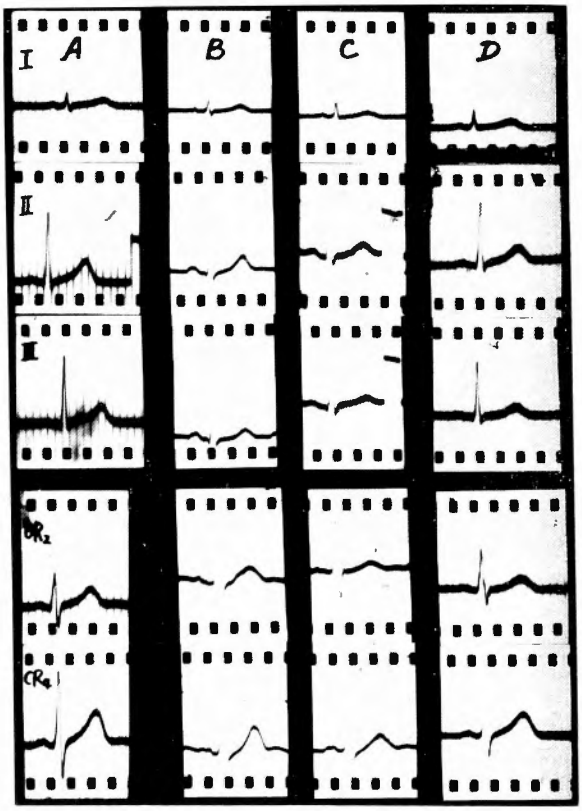


Fig. 10. Case 2. Serial electrocardiograms after gastrectomy. Lowered amplitude of T wave was observed until he took a meal on 3rd postoperative day. A. Before operation. Serum K : 4.0mEq./L. B. 24 hours after operation. Serum K : 4.0mEq./L. C. 2nd postoperative day. Serum K : 3.8mEq./L. D. 3rd postoperative day. Serum K : 3.7mEq./L.

Fig. 11. Case 3. Serial electrocardiograms after gastrectomy. A. Before operation. B. Several hours after operation. C. 24 hours after operation. Serum K : 3.8mEq./L. Serum Na : 154mEq./L. D. 2nd postoperative day. T waves in leads II, CR_2 and CR_4 lowered. Serum K : 3.3mEq./L. Serum Na : 167mEq./L. E. 3rd postoperative day. Amplitude of T wave increased. Serum K : 4.4mEq./L. Serum Na : 154mEq./L.

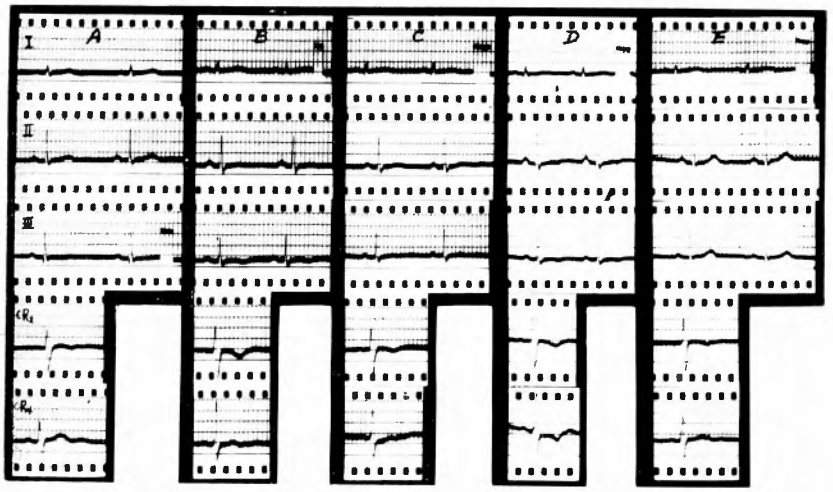


Fig. 12. Case 4. Serial electrocardiograms after gastrectrectomy. A. Before operation. B. 3rd postoperative day. C. 5th postoperative day. D. 8th postoperative day. Anorexia and abdominal distension progressively increased with lowered amplitude of T wave and prominent U wave in leads II and CR_4. E. 10th postoperative day. After administering 6g of potassium chloride by mouth. Note marked improvement.

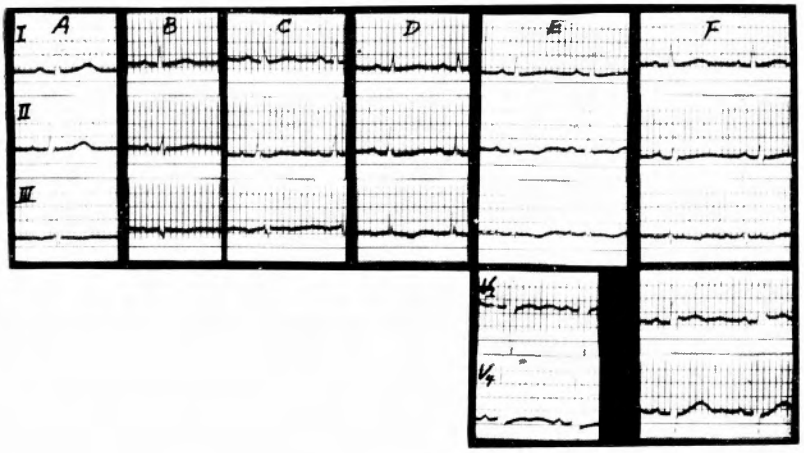


Fig. 13. Case 5. Serial electrocardiograms after gastrectomy. A. Before operation. B. 2 hours after gastrectomy. C. 24 hours. D. 2nd postoperative day. E. 3rd postoperative day. Lowered amplitude of T wave with prominent U wave was observed. Serum K : 6.0mEq./L. F. 4th postoperative day. After administering 4g of potassium chloride by mouth, electrocardiogram and clinical findings improved remarkably.

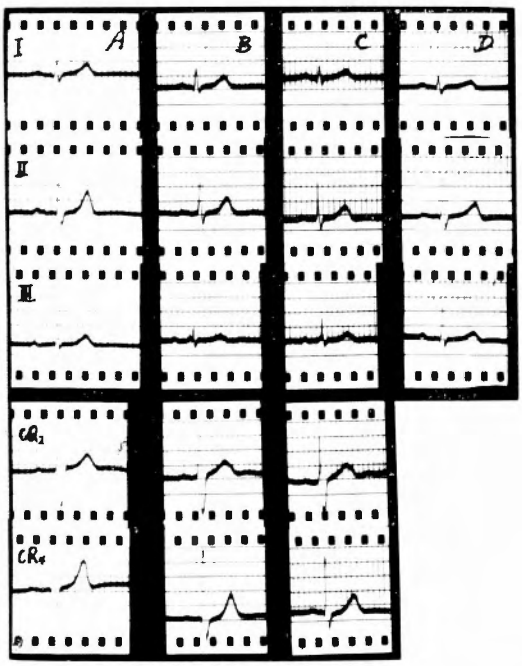


Fig. 14. Case 6. Serial electrocardiograms after gastrectomy. The patient complained of persistent vomiting caused by mechanical obstrution of gastro-enteric anastomosis. He was recovered by routine therapy on 8th postoperative day. A. Before operation. B. 2 days, C. 4 days, D. 7 days after operation. There was no specific change in electrocardiogram.

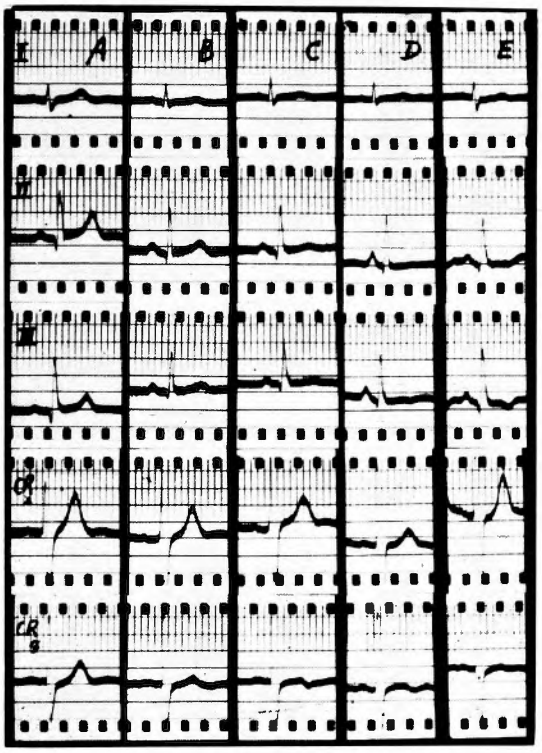


Fig. 15. Case 7. Serial electrocardiograms after gastrectomy with perforative peritonitis. A. Before operation. B. 24 hours, C. 2 days, D. 4 days, E. 6 days after operation. The change is quite similar as presented in Fig. 1 and 2.

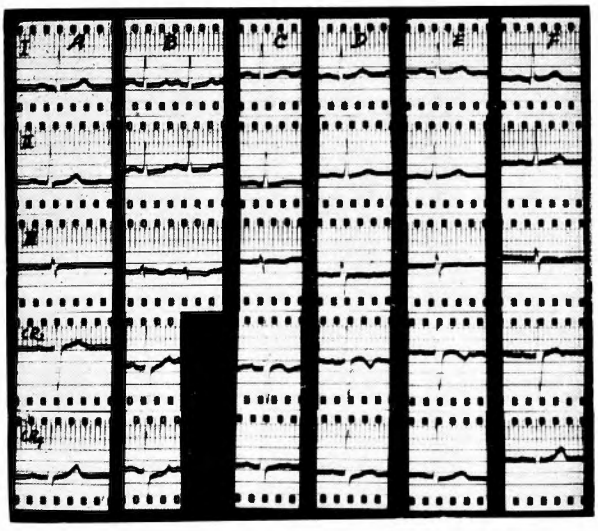


Fig. 16. Serial electrocardiograms after radical operation for carcinoma of rectum. Depressin of ST segment and lowered amplitude of T wave progressively returned to normal configuration. A. Before operation. B. Immediatly after operation. C. 24 hours, D. 2 days, E. 3 days, F. 4 days after operation.

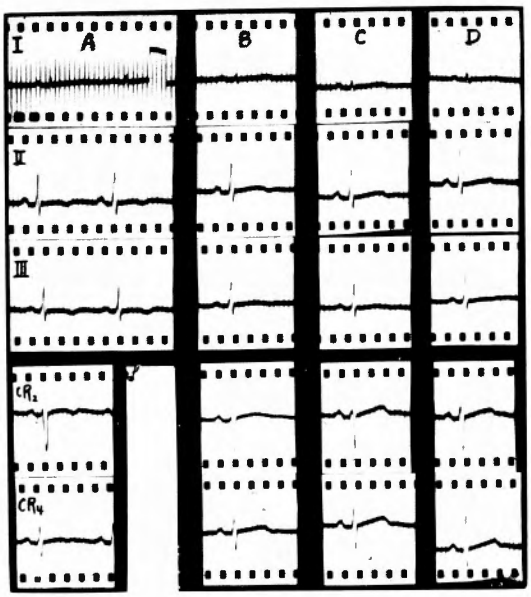


Fig. 17. Case 1. A. Note low or inverted T wave with U wave in limb and precordial leads. Serum K : 4.3mEq./L. Serum Na : 139mEq./L. B. 2 hours after administering 1g of potassium chloride. Note upward increased amplitude of T wave in leads II and CR_4 with obscure U wave. Serum K : 5.1mEq./L. Serum Na : 137mEq./L. C. 24 hours after. (3g of potassium chloride was administered.) Serum K : 5.3mEq./L. Serum Na : 135mEq./L. D. 48 hours after. (6g of potassium chloride was administered.) Serum K : 4.6mEq./L. Serum Na : 139.5mEq./L.

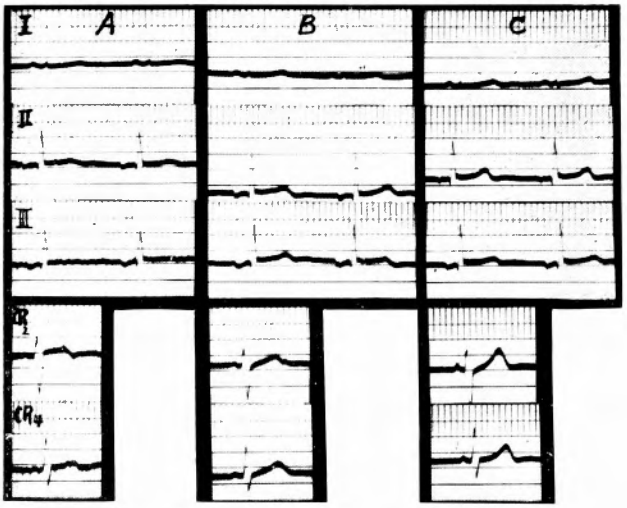


Fig. 18. Case 2. A. Note lowered amplitude of T wave in limb and precordial leads. Serum K : 4.8mEq./L. Serum Na : 140mEq./L. B. 24 hours after. (5g of potassium chloirde was administered by mouth.) Serum K : 4.8mEq./L. Serum Na : 140mEq./L. C. 2 days later. T wave returned to normal amplitude. Serum K : 4.0mEq./L. Serum Na : 131mEq./L.

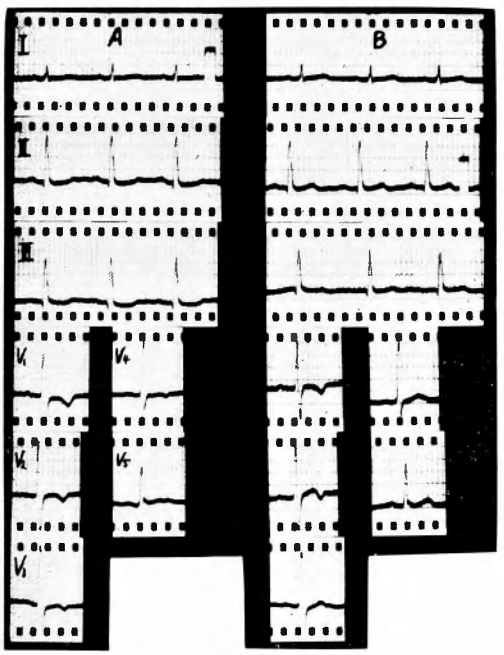
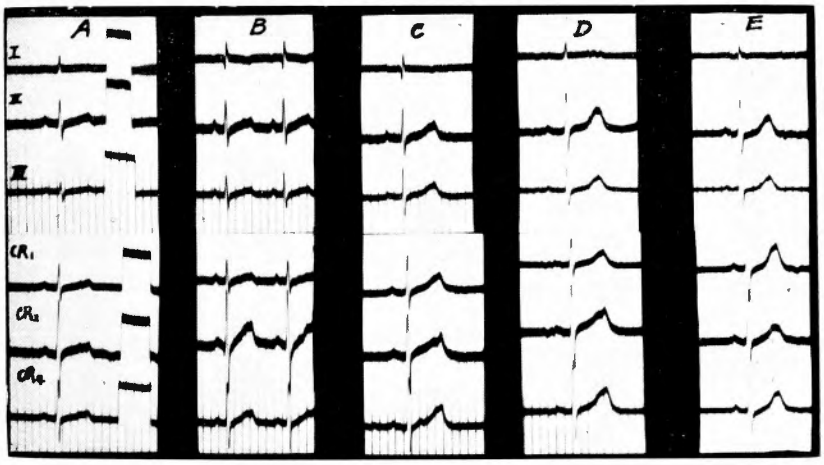


Fig. 19. Case 3. A. Serum K : 4.0mEq./L. B. One hour after administering 1g of potassium chloride by mouth. Serum K : 4.4mEq./L.

Fig. 20. Electrocardiographic patterns in potassium depletion (CR_4). A. Normal. B., C. Lowered amplitude of T with a double summit due to superimposition of U wave on T. D., E. Inversion of T wave with U wave, characteristic of potassium depletion.

Fig. 21. Animal experiment.

		Control	Gastrectomy ↓	P. O. Day 1	2	3	4
Serum	K.	3.5		4.0	3.3	2.8	2.9
DOCA			5mg.	5mg.	5mg.	5mg.	



total K content in heart muscle : 322.2mEq./kg.
intracell. K conc. : 79.1mEq./L.
extracll. K conc. : 2.7mEq./L.
cardiac K quotient : 29.3

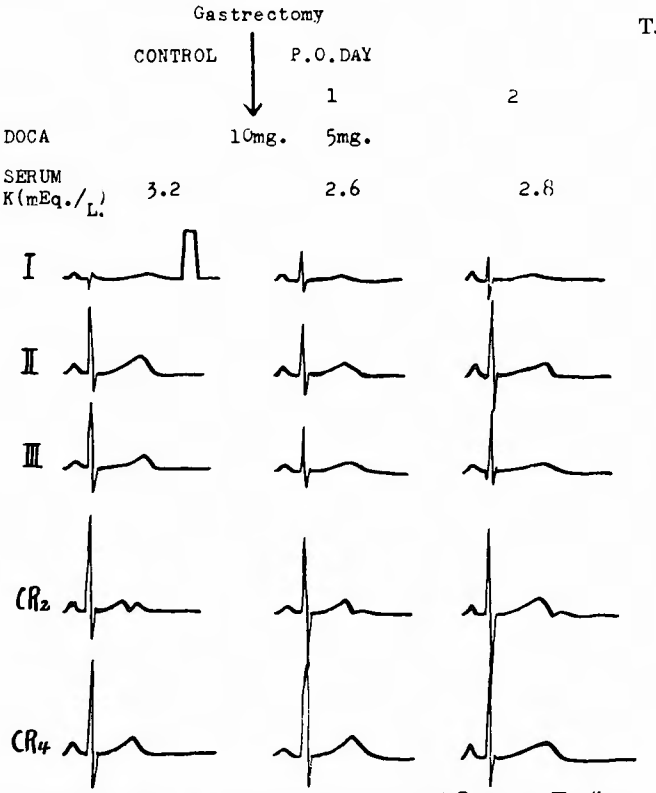


Fig. 22. total K content in heart muscle : 270.5mEq./kg.
intracell. K conc. : 74.6mEq./L.
extracell. K. conc. : 2.65mEq./L.
cardiac K quotient : 28.1

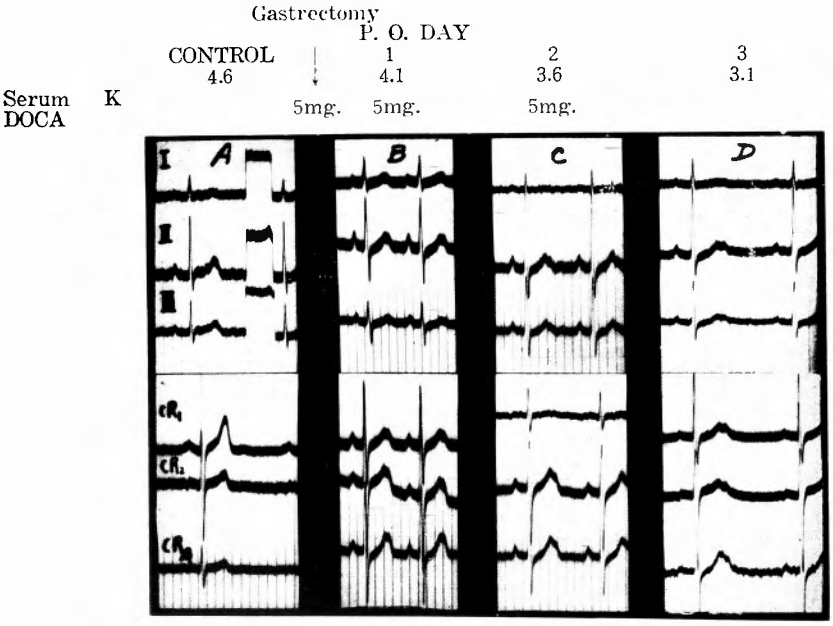


Fig. 23. total K content in heart muscle : 343.9mEq./kg.
intracell. K conc. : 120.7mEq./L.
extracell. K conc. : 2.9mEq./L.
cardiac K quotient : 41.6

Fig. 24. total K content in heart muscle : 308.9mEq./Kg. T.OGATA XII
intracell. K conc. : 92.5mEq./L. extracell. K conc. : 2.21mEq./L.
cardiac K quotient : 41.3

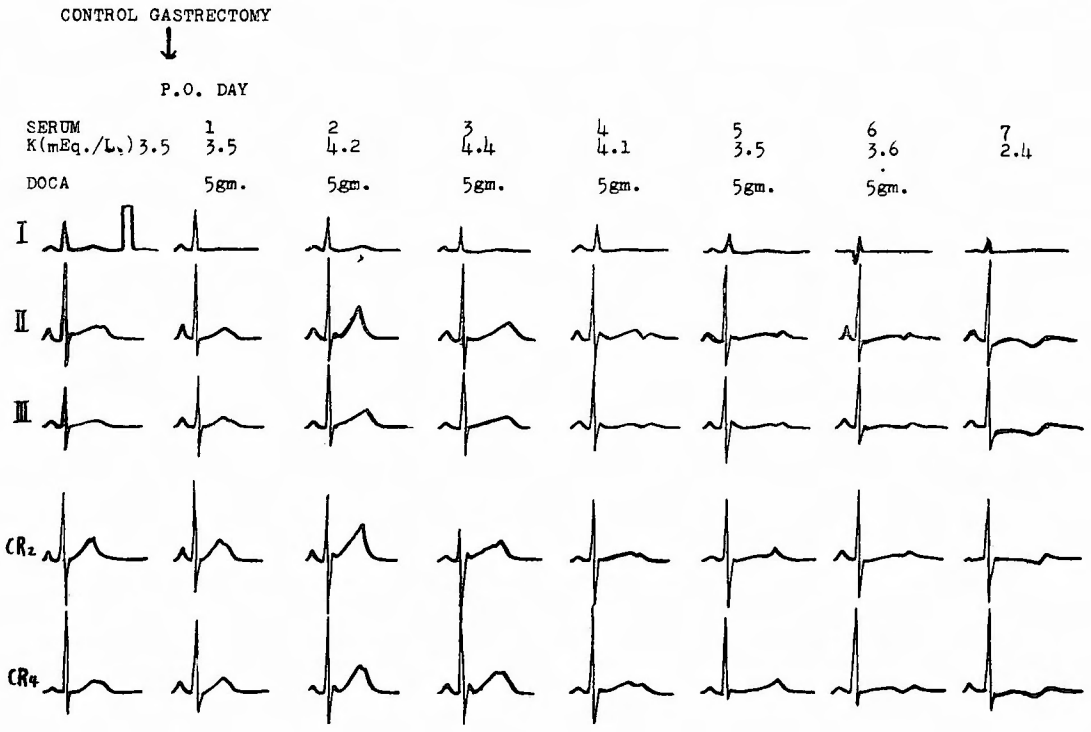
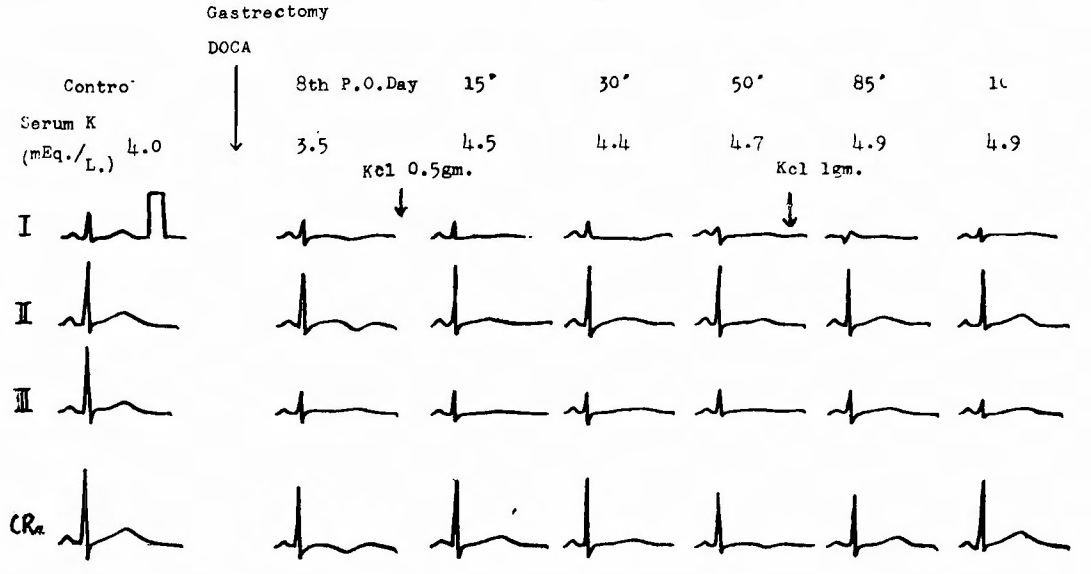


Fig. 25.
Effect of potassium chloride on the induced electrocardiographic change.



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胃切除後の心電図変化，特にカリウム缺乏症との関係について

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助手　緒　方　　武

腹部外科手術施行患者の術前，術後の心電図を検討中，胃切除術後に屢々異常所見を認め，而もこの所見がカリウム欠乏症と関係のあることを明かにすることが出来た．即ち

① 胃切除術施行患者84例中27例に於て，ST低下，T波の平低乃至逆転，U波出現等の異常所見出現を認めたが，その中25例は強い全身倦怠感，食慾不振，悪心，嘔吐，呼吸困難等の臨床症状を訴えた．上述の心電図変化とかゝる術後病苦との間に並行関係が認められたのである．

② 而もこのような心電図変化が，凡て術後に起つた腹膜炎，機械的腸閉塞，ショック等によつて結果されたものでないことを明白にした．

③ かかる心電図変化の原因が手術による副腎皮質機能亢進，術後の絶食或は胃内容吸引，輸液等による電解質，特にカリウムの代謝異常によるものではないかと考え，別にカリウム欠乏症と確実に診断された患者28例に於て検討された心電図と，上述症例のそれとを比較したところ，両者全く同一の変化であることを確認した．従つて胃切除術後に起つた前述のような心電図変化は，カリウム投与によつて直ちに軽快するのみならず，予防的にカリウムを投与するとかかる変化を来さないことを確めえた．

④ しかし，血清カリウム濃度とかゝる心電図変化との間には並行関係が認られない．よつて動物実験上にてこの点を匡した．即ち試獣犬に胃切除術及びDOCAを連続投与してカリウム欠乏症を起させ，その心筋について細胞内・外カリウム濃度を測定した結果，Kühnsが主張しているように，それらのアンバランスと心電図との間に並行関係のあることを確認した．

⑤ 胃切除術後，心電図を連続撮影すれば，カリウム欠乏症を容易に発見することが出来，従つて早く治療することも出来る．特に胃切除後原因不明な嘔吐がつゞく時は，この点を充分に考慮する必要がある．